

Field Flashing a Synchronous Generator Using Batteries



Team “Flash” Members

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 - AVR expert
 - Hardware System
 - Client Contact
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 - Hardware System
 - Portfolio
- Bruno Loza
 - RTDS
 - Wiki Page
 - Budget



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 - Technical Advisor
- Nikhil Pai
 - Primary Client Contact

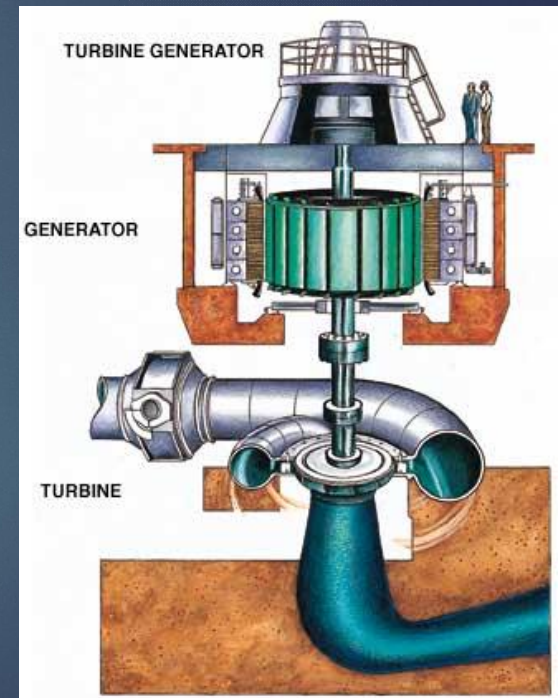
Problem Statement

- Design a black start field exciter system for the 15-kVA synchronous generator in the Buchanan Engineering Lab (BEL) to be used for research on black start conditions



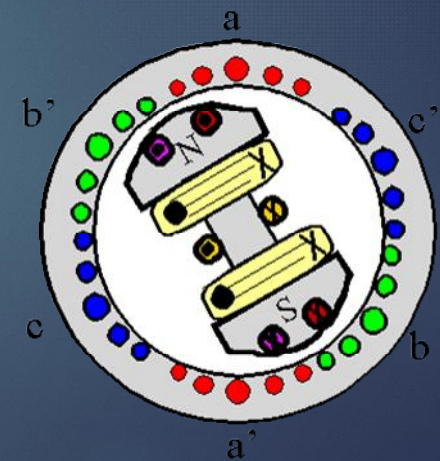
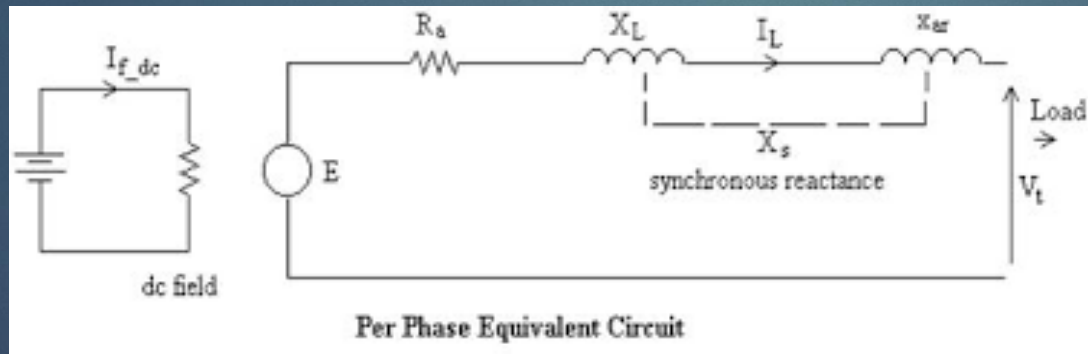
Black-Start

- Definition
 - The process of restoring a power station to operation without relying on the external electric power transmission network.
- Primary applications
 - Hydropower
 - Diesel generators

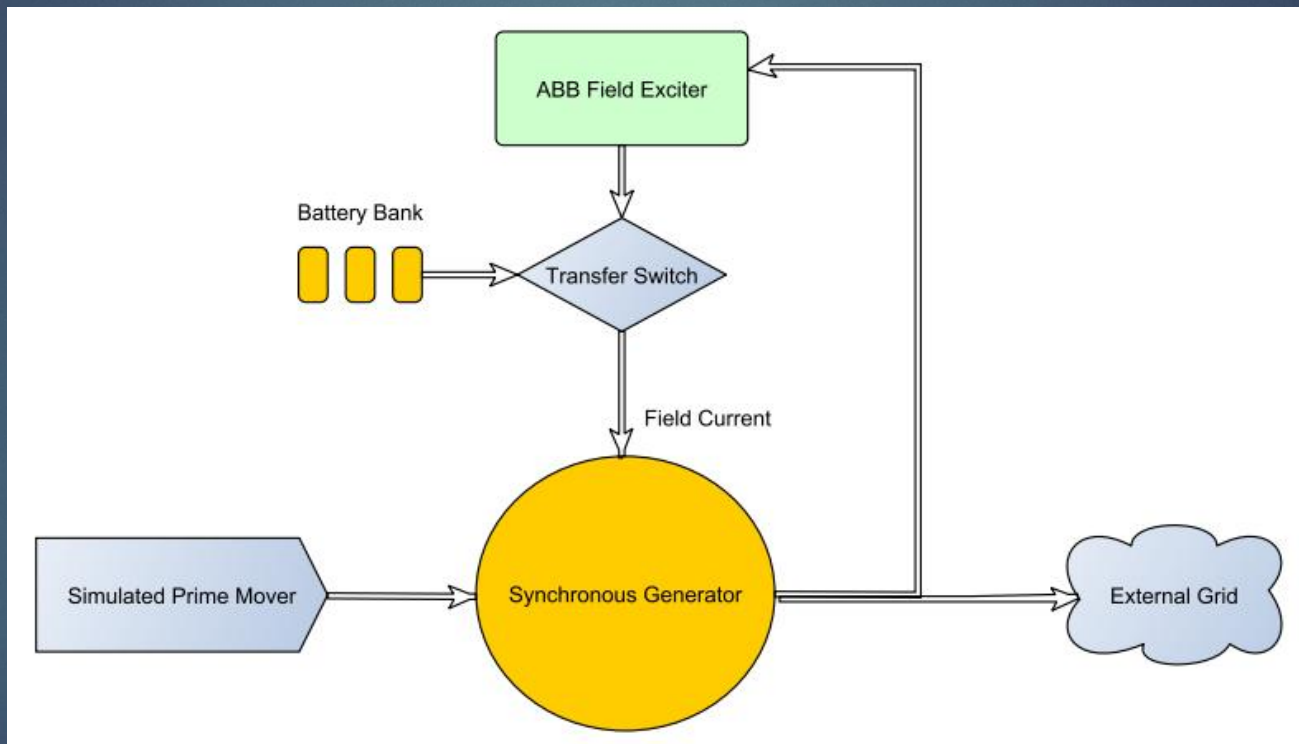


Exciting a Synchronous Generator for a Black Start

1. The rotor is spun by an easily started mechanical prime mover like a hydro turbine or diesel engine.
2. DC current is applied to the rotor windings producing a rotating magnetic field.
3. A 3-phase AC voltage is induced on the stator windings.

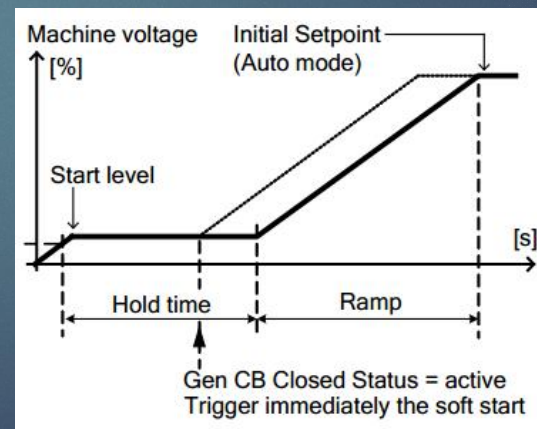


Project Goal

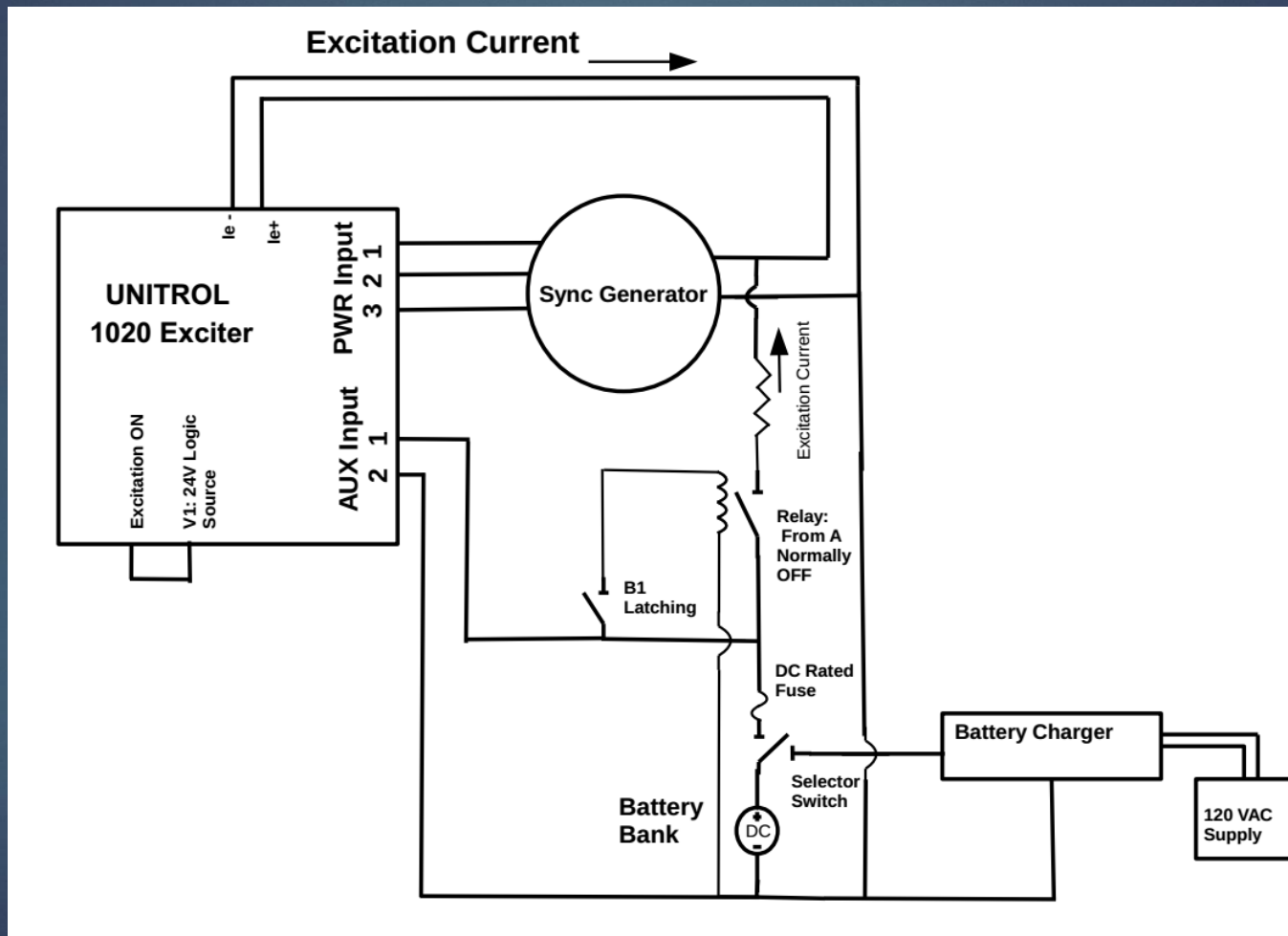


Starting Requirements

- Correct frequency
 - Generator cannot be excited until rotor is spinning at rated frequency
 - Attempting to excite machine with a stationary rotor would saturate the machine core
- Soft Start
 - Needed to reduce the magnitude of the inrush currents to the synchronous generator field windings
 - Power electronic control
 - Added series resistance



Black Start System Schematic



System Process:

- 1- Selector switch => System On

Connects battery to AUX power supply on AVR control system

- 2- Prime mover spins rotor to initiate a black start

- 3- Press flash field button

Turns on relay connecting batteries to field windings of the generator

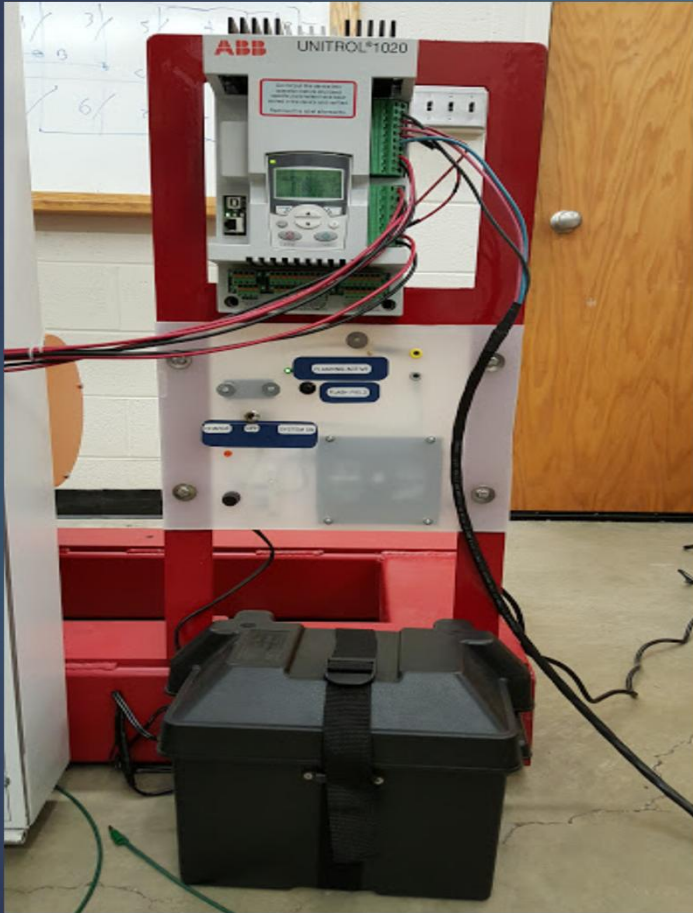
- 4- AVR ramps up field current using machine output power

- 5- Release flash field button

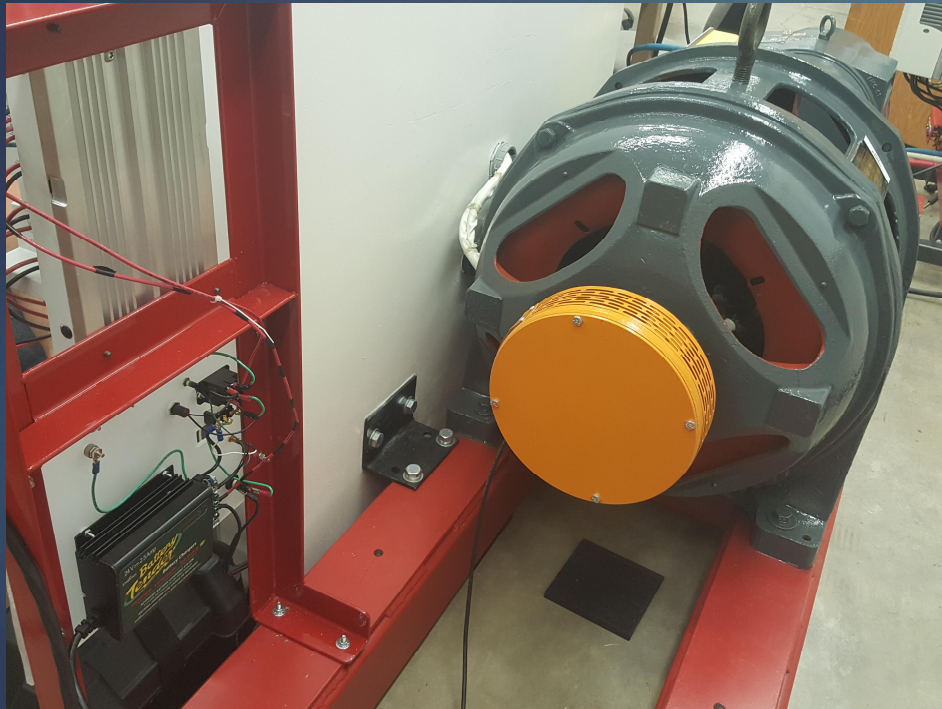
Disconnects Batteries from generator field windings

- 6- AVR controls excitation in steady state operation

Final System Hardware

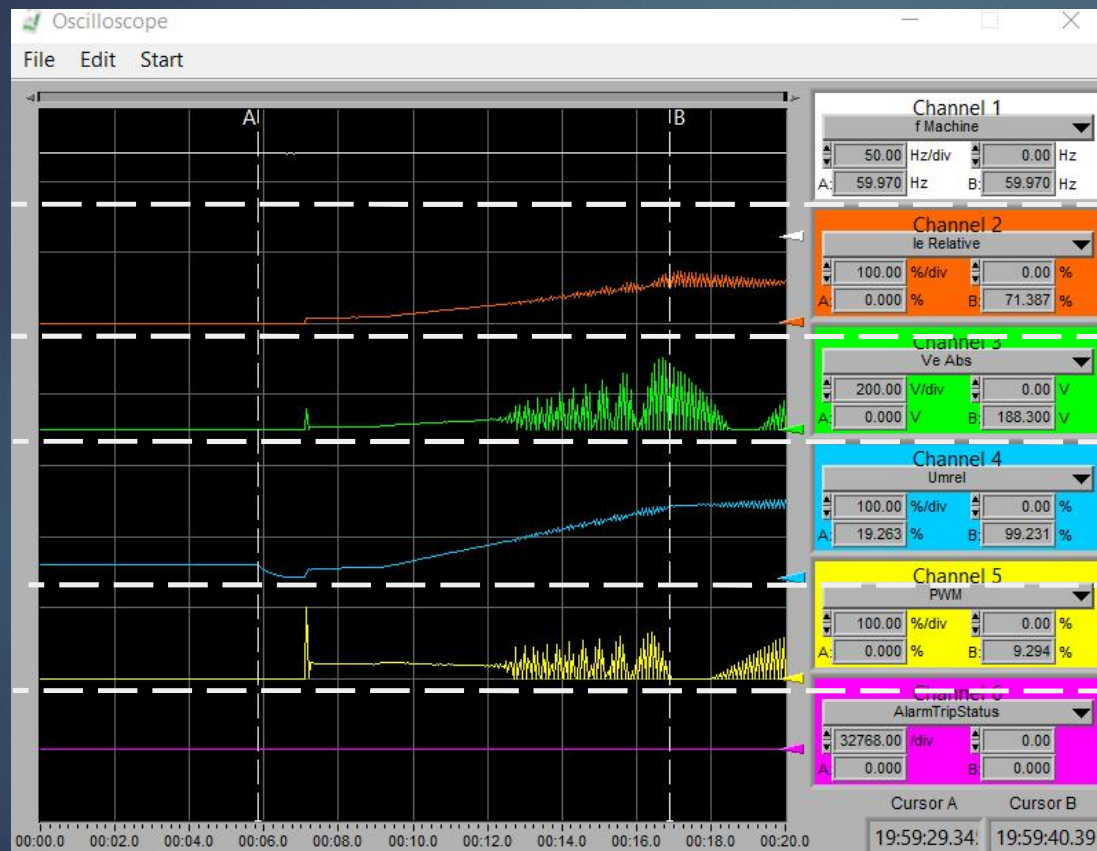


Final System Hardware



System Test Video

AVR Recorded Experimental Data



Machine frequency (Hz)

Relative field current (%)

Field voltage (V)

Relative machine output voltage (%)

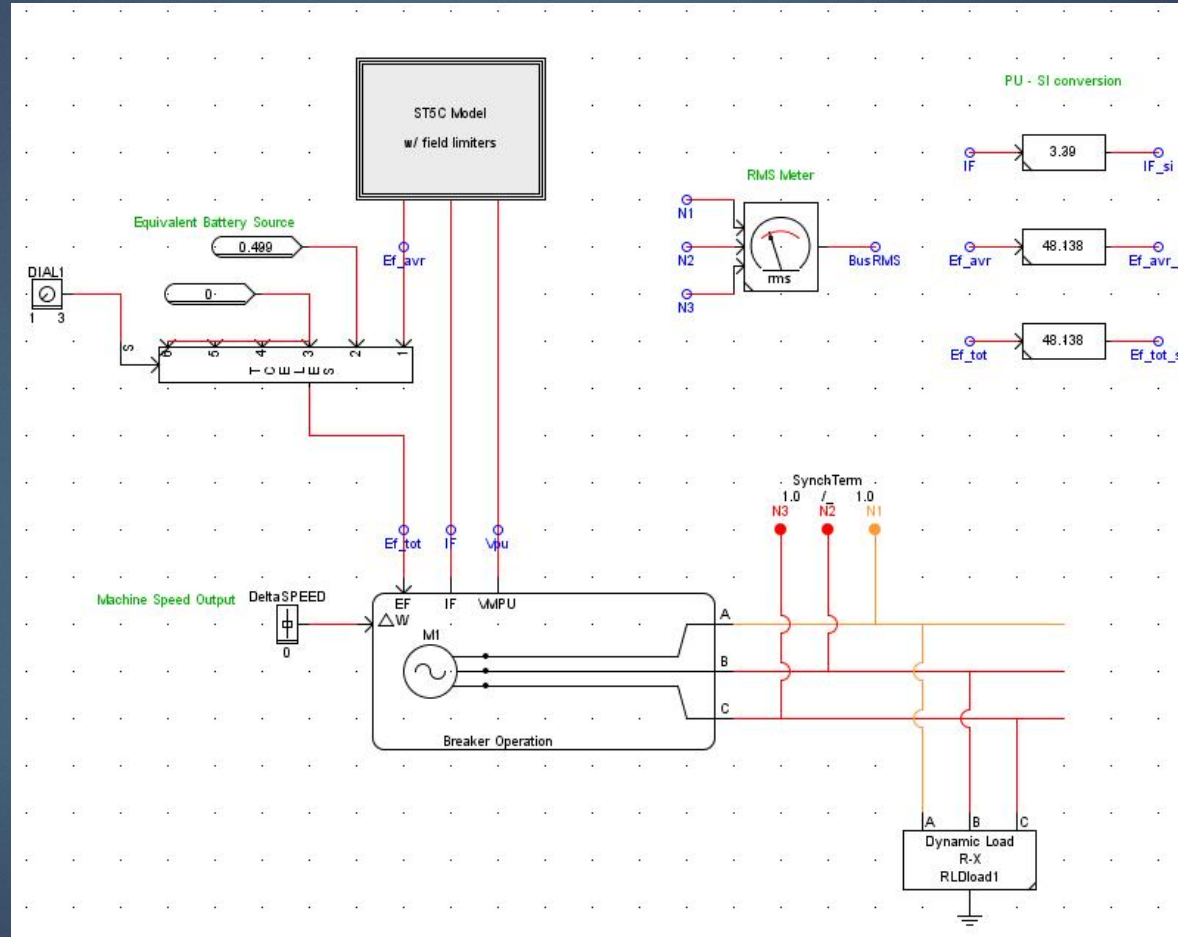
PWM (%)

*Reaches steady state operation
in 11 seconds*

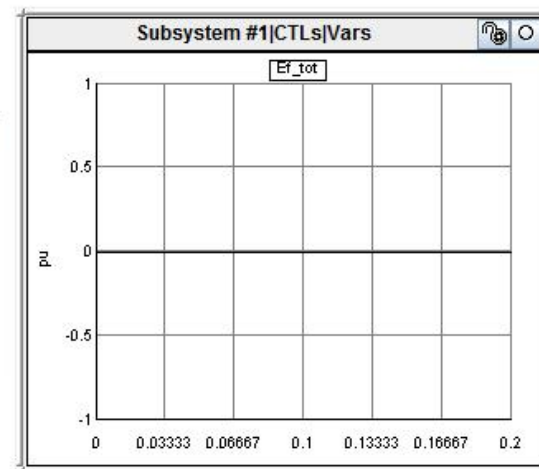
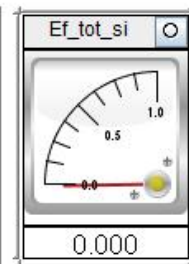
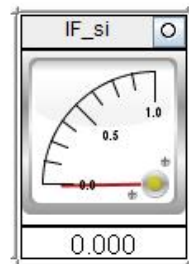
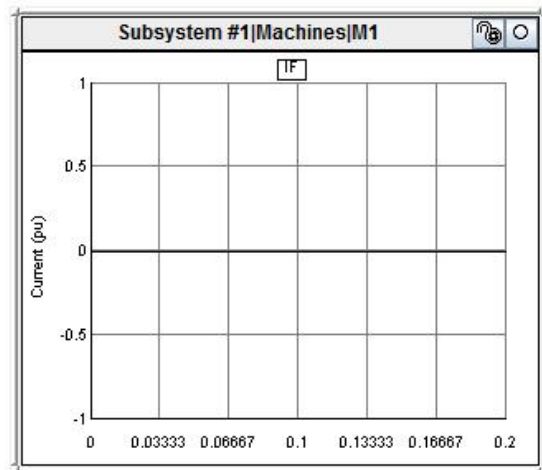
RTDS (Real Time Digital Simulation)

- RTDS is used for hardware-in-the-loop simulation of power systems and controls
- RTDS System Components
 - Synchronous Machine Model
 - AVR Model from ABB
 - Variable Load
 - Black-start Transfer Switch

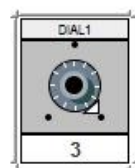
RTDS – Battery bank and AVR



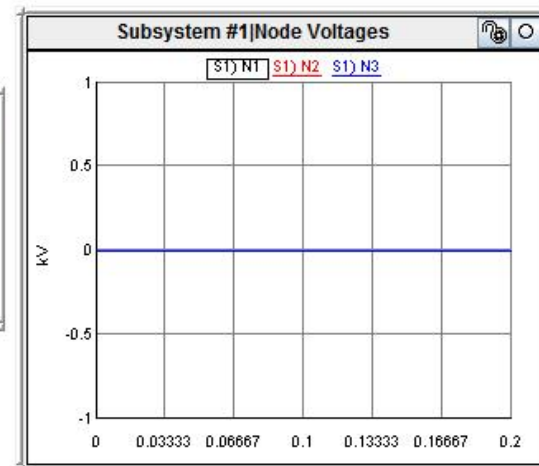
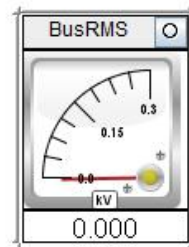
No Excitation to System



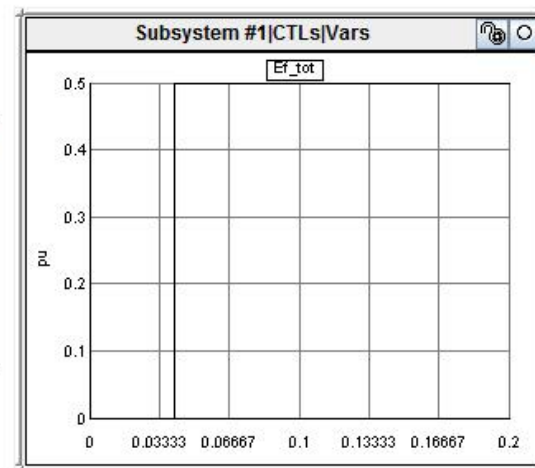
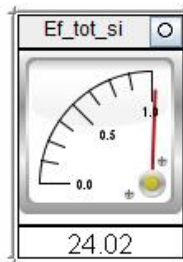
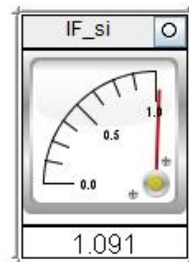
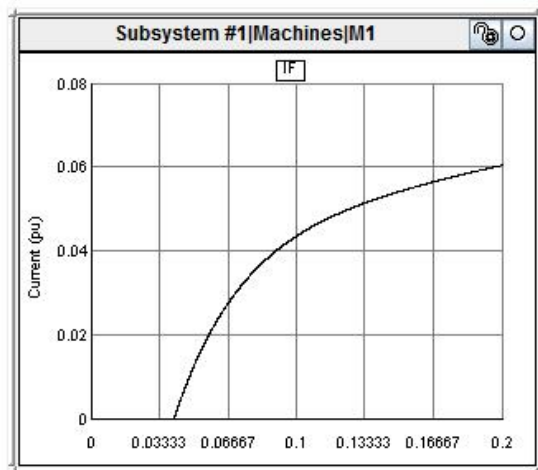
Excitation Switch



- 1 = AVR Excitation
- 2 = Battery Excitation
- 3 = No excitation



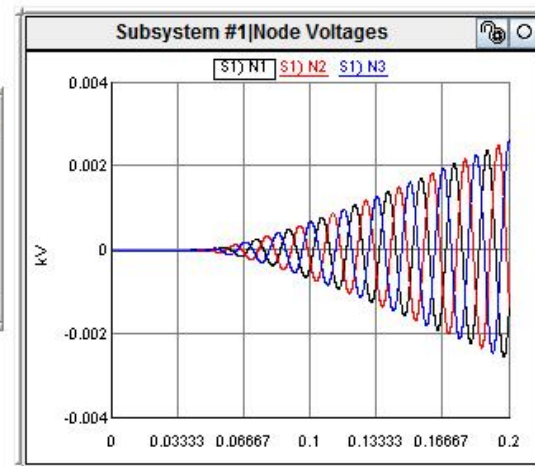
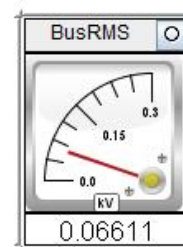
Excitation from Battery



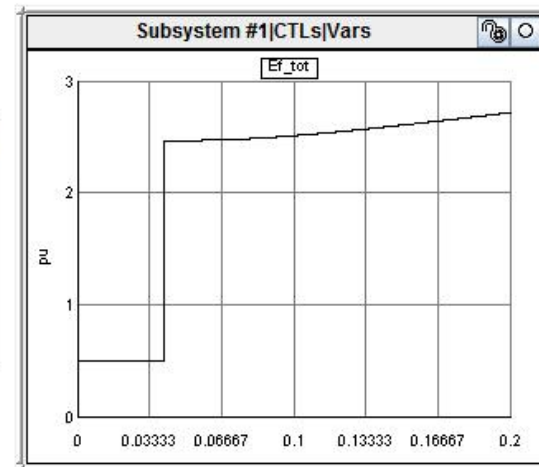
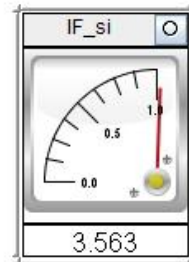
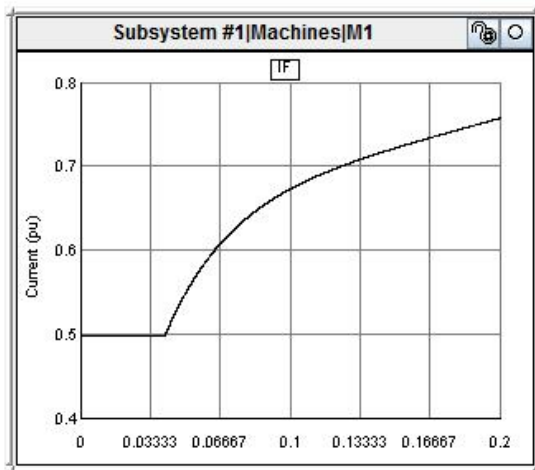
Excitation Switch



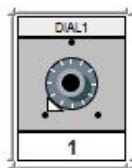
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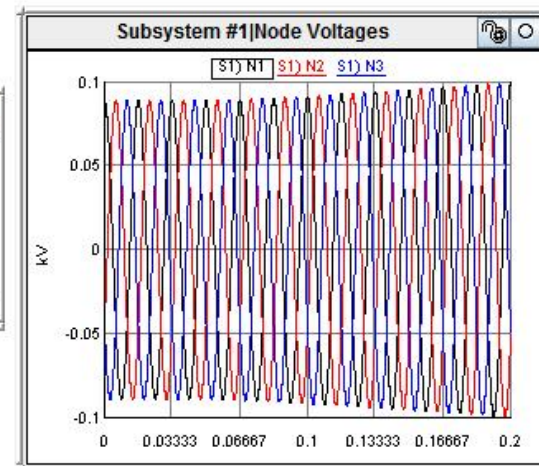
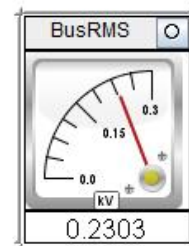
Switch from Battery to AVR excitation



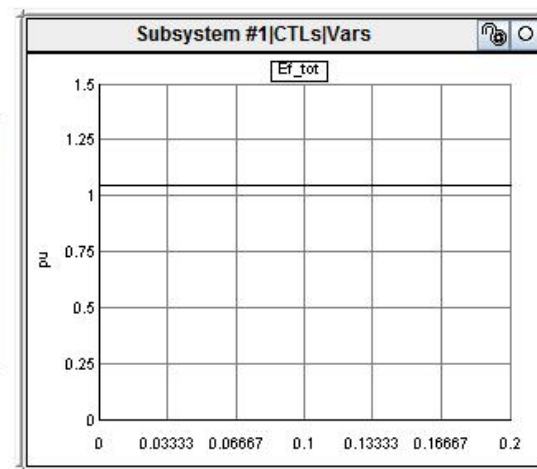
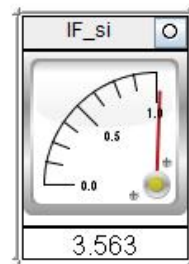
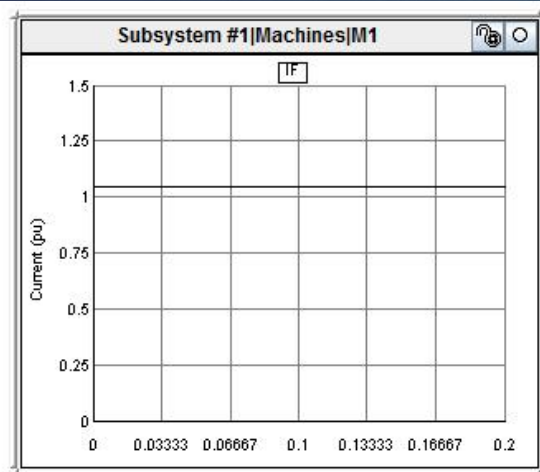
Excitation Switch



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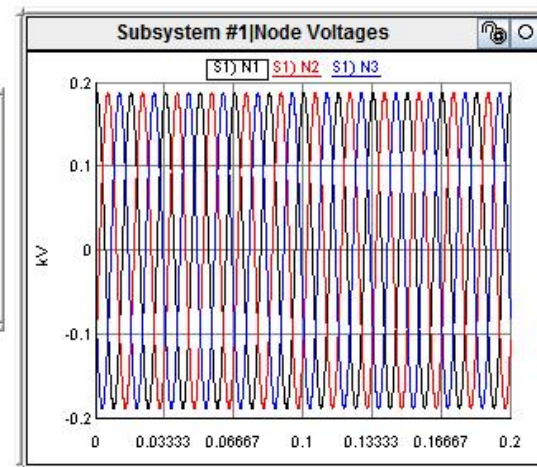
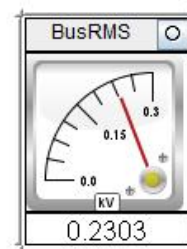
Steady State Operation



Excitation Switch



- 1 = AVR Excitation
- 2 = Battery Excitation
- 3 = No excitation



Thank you

- Dr. Herbert Hess
- Andy Miles
- Mike West
- Greg Klemesrud
- John Jacksha



Questions?